



U.S. Department of Energy
Energy Efficiency and Renewable Energy

industrial technologies program

ITP Corporate Peer Review: Metal Casting Sub-Program

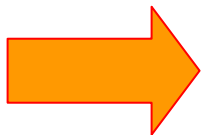


March 9, 2004



Snapshot of the U.S. Metal Casting Industry

- Small business industry
- Vital to the U.S. economy and national defense
- Struggling to compete with low-cost imports
- Few resources to invest in R&D, particularly high-risk, long-term efforts on revolutionary technologies
- Significant improvements in energy efficiency over the last 20 years, but further gains needed to remain viable



Need for Industry/Government Partnership



Energy Saving Opportunities for Metal Casting

Key Processes:

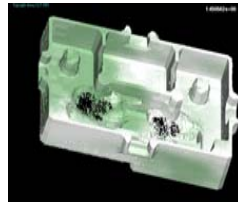
Sand Casting



**Energy
Efficiency
Challenges:**

**Yield
Metal Filling
Spent Sand**

Lost Foam



**Pattern Making
Metal Filling/Pyrolysis
New Bead Material**

Die Casting



**Die Technology
Process Modeling
Alloy Development**

Semisolid



**Low-Cost Feedstock
SSM Rheology
Yield Stress/Microstructure**

**Permanent
Mold**



**Gating
Mold Filling
Heat Transfer**



ITP Program Structure

Industrial Technologies

Portfolio & Financial Mgmt.

Technology Delivery
Assessments, Best Practices

Advanced Process Systems

Metals & Mining

Mining, Steel, **Metal Casting**,
Aluminum

Materials, Sensors, & Automation

Glass, Materials, Sensors

Chemical and Enabling Technologies

Chemical & Allied Processes

Chemicals, Forest Products

Industrial Energy Systems

Combustion, Supporting
Industries, Tool Development

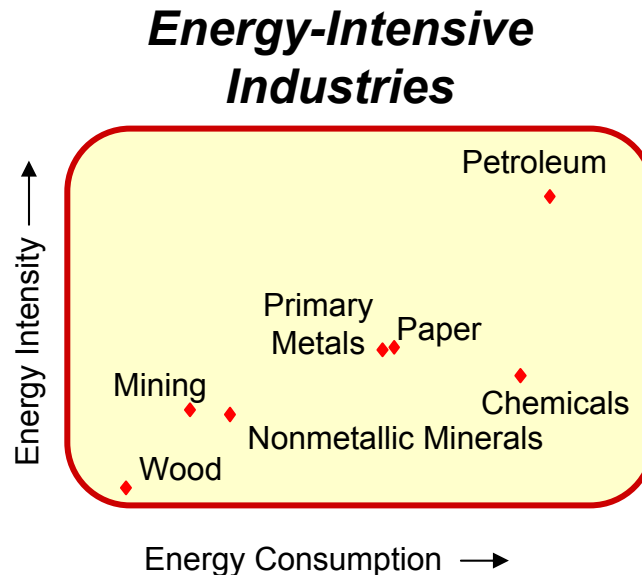
Golden Field Office, Regional Offices, NETL



EERE/ITP Mission & Goals Guide the Metal Casting Sub-Program

EERE/ITP

- EERE:
Increase the energy efficiency of industry
- ITP:
By 2020, contribute to a 30% decrease in the energy intensity of energy-intensive industries



Metal Casting Sub-Program

- Reduce the energy intensity of making metal castings
- Improve the metal casting industry productivity and reduce yield losses
- Help the metal casting industry maintain its competitive position



Analysis-Guided Planning

Activity

- Program Goal Setting
- Technology Area Planning
 - Focus Areas
 - Project Solicitation



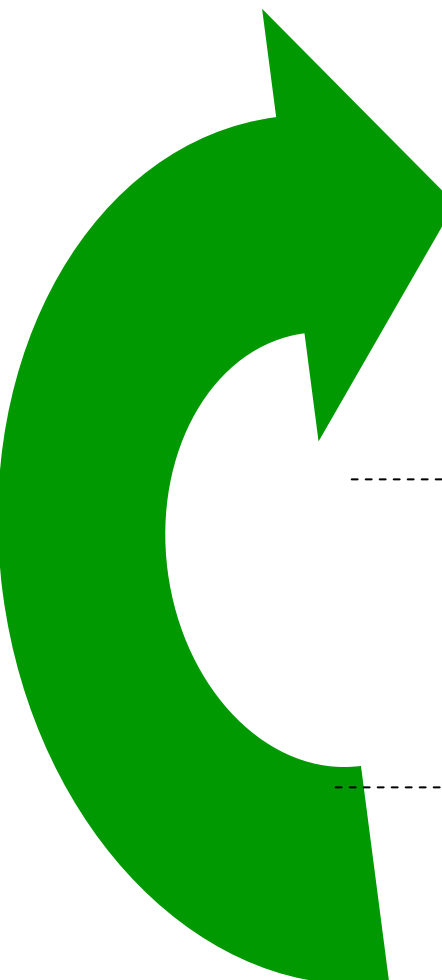
Project Selection
& Execution



Assessment
& Evaluation

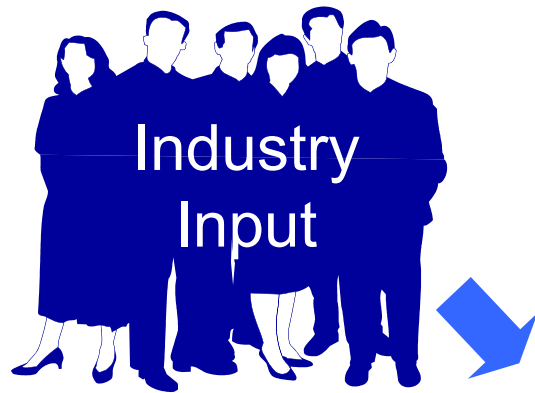
Supporting Analysis

- Energy Footprints and Other Energy Studies
- Bandwidth Studies
- Barrier/Pathway Approach
- Expert Peer Reviews
- GPRA
- Detailed Milestone Tracking (CPS)
- Corporate & Portfolio Peer Review
- Follow-Up Studies





Program Planning Inputs



ITP
Strategic
Plan



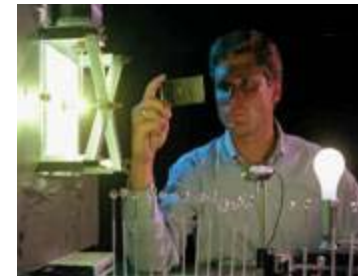
Analytic
Studies



Prioritized Focus Areas



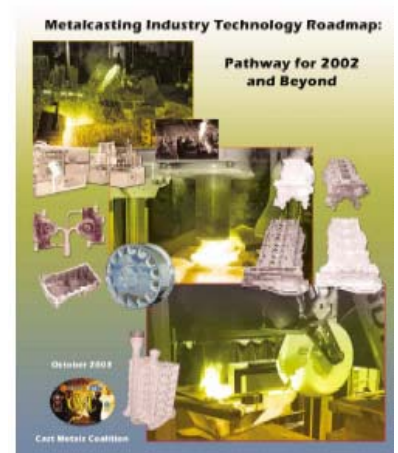
Barriers/R&D Pathways





Industry Inputs

- *Metal Casting Vision*
 - Published by U.S. metal casting industry 1995 and updated 2002
- *Metal Casting Technology Roadmap*
 - Published by U.S. metal casting industry 1998 and updated 2003
 - Identifies metal casting industry priorities for reducing energy intensity and increasing competitiveness





Analytic Tools for Metal Casting Sub-Program Planning

Energy and Environmental
Profile
of the
U.S. Metal Casting Industry
September 1999

Prepared by
Energetics, Incorporated



Prepared for
U.S. Department of Energy
Office of Industrial Technologies

*Metal Casting Industry
Energy and Environmental
Profile (Sept. 1999)*

Energy Use in Selected Metal
Casting Studies - 2003

February 2004



Prepared for
U.S. Department of Energy
Office of Industrial Technologies

*Energy Use in Selected Metal
Casting Facilities - 2003
Study (Feb. 2004)*

Theoretical/Practical
Minimum Energy Use in
Metal Casting Operations

February 2004

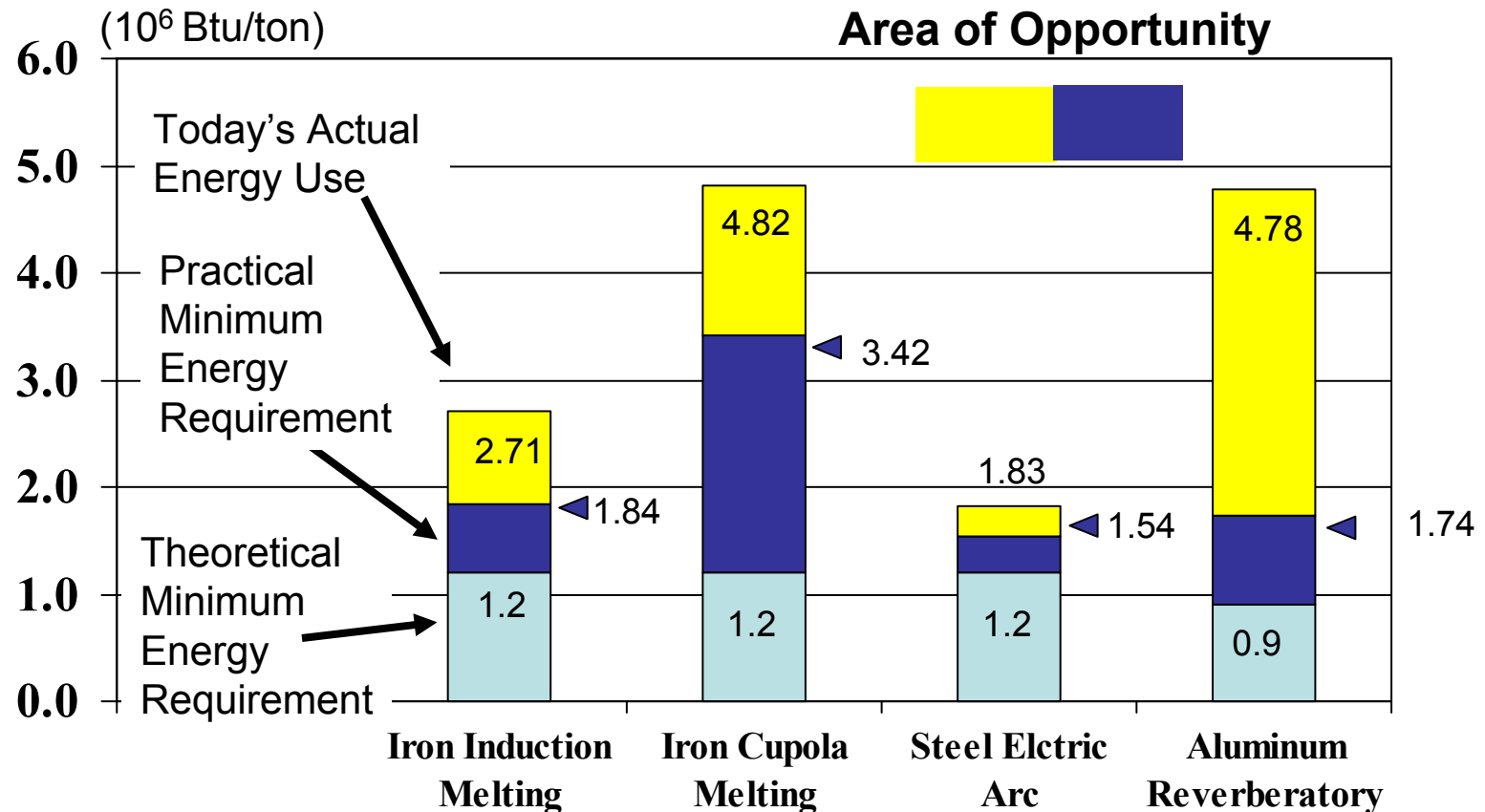


Prepared for
U.S. Department of Energy
Office of Industrial Technologies

*Theoretical/Practical
Minimum Energy Use in
Metal Casting Operations
(March 2004)*

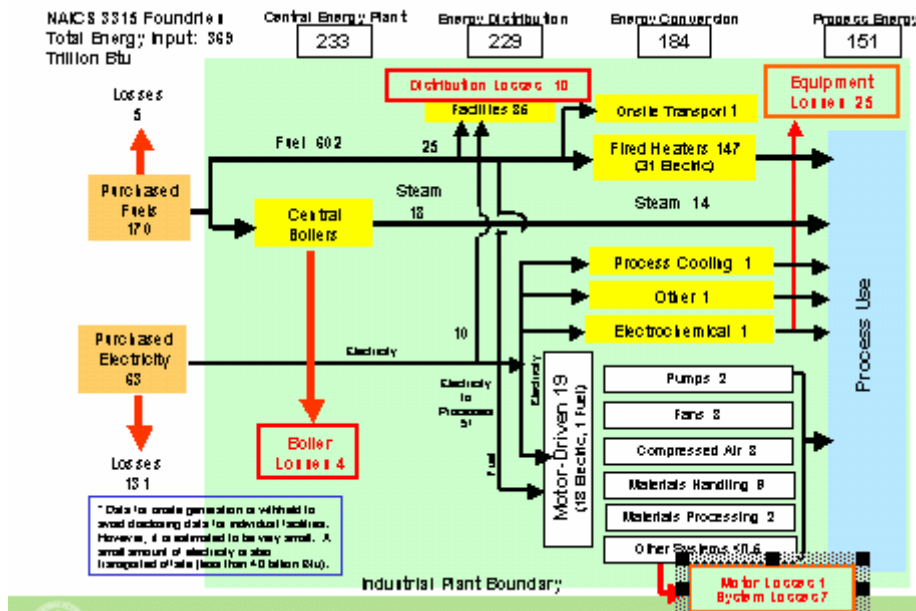


Metal Casting Industry Bandwidth Analysis





Metal Casting Energy Footprint Analysis



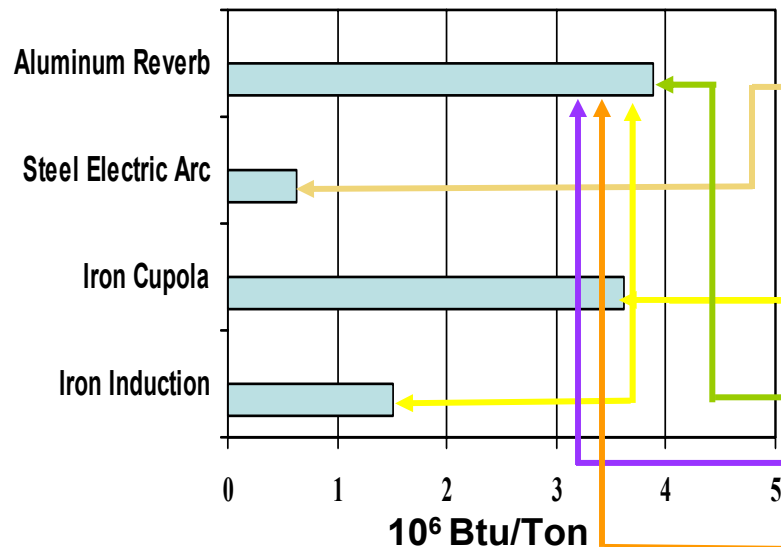
- Benchmark energy consumption for the U.S. metalcasting industry, through energy assessments at 15 representative facilities
- Evaluate detail energy use in heating, ventilation, melting, emission control equipment, and associated manufacturing and support equipment.



Analytic Basis for Metal Casting Sub-Program Priorities

- Used analytic tools to identify the best opportunities for reducing energy intensity
- Set focus areas based on gap between current use and theoretical need
- Quantified potential energy savings in each focus area

Metal Casting Energy Savings Potential Bandwidth



Research Areas:

Advanced Melting: Establish new melting technologies and practices

1 Yield Improvement and Scrap Reduction in steel

Innovative Casting: Advance casting processes and practices that increase yield and reduce scrap, thus reducing melting requirements

2 Computer Models & Alloy Diversification in Lost Foam

3 Design Tools to Improve Die Casting

4 Semisolid Metal Feedstock

5 Improvements in Permanent Mold Casting



Focus Area 1. Advanced Melting

Barrier-Pathway Approach and Project Selection

Barriers



Pathways



Metrics

- Melt efficiency
 - Metal transfer heat loss
 - Scrap/revert reduction
 - Mold yield Improvement
- Establish new design methodologies
 - Establish new melting practices

Metric	2020
Energy Savings	31 trillion Btu
Cost Savings	\$137 million
Carbon Reduction	0.48 MMTCe

**Issued the *Melting and Innovative Casting* solicitation in FY03;
projects selected based on formal Merit Review**



Advanced Melting R&D Pathways: Assumptions and Targets

Energy

- 10% increase in yield at a typical steel casting facilities
- 25% increase in yield at a steel casting facilities with an optimized casting system

Markets

- Commercial introduction in 2010
- Adopted by 40% of the applicable U.S. market
- Market saturation in 10 years

Other

- Productivity benefits that arise from penetration of their technologies.



Advanced Melting Example: Yield Improvement and Defect Reduction in Steel Castings (CPS# 1653)

Technology Description:

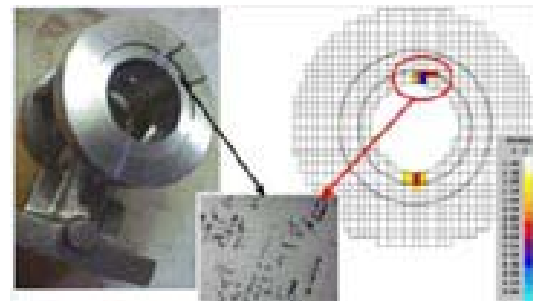
- Use computer modeling for defect prediction in steel castings, which in turn enables the rewriting of new standards
- Look at unconventional yield improvement and defect reduction techniques, examining both riser pressurization and filling with a tilting mold.

Benefits

- 10% increase in yield at a typical steel foundry
- 25% increase in yield at an optimized casting facility
- Increased capacity and productivity at steel foundries
- Expands applications for steel castings

Status

- Writing rules manual for high alloy steel
- In plant trials of pressurized risers



Numerical simulation results for a steel valve indicate the presence of microporosity, as was found in the gasket.



Advanced Melting: Management by Milestone

ITP Major Milestones (CPS #1653)

Aug 05	Radiographic Standards Model
Sept 06	Simulation & Prevention of Hot Tear
Jun 08	Parametric Design / Process Modeling Tools

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Corporate Planning System

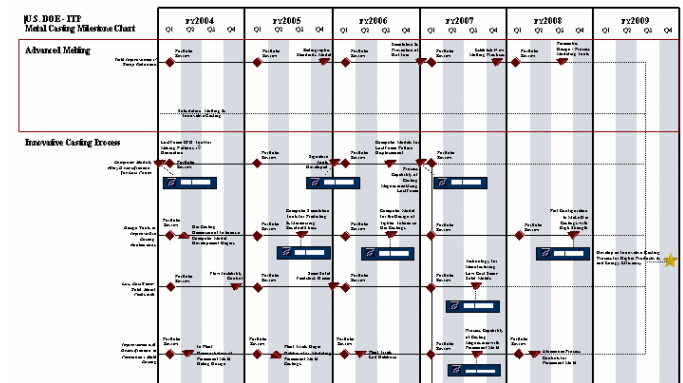
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Task 3.4 Conduct controlled experiments for model calibration	On Track	Pgm Mgr	3/31/2004	3/31/2004	edit delete
Task 3.5 Perform casting trials for model testing	On Track	Pgm Mgr	11/30/2004	11/30/2004	edit delete
Task 1.1 Kick-off meeting	Complete	Pgm Mgr	12/31/2001	12/31/2001	edit delete
Task 1.3 Perform casting trials	Complete	Pgm Mgr	5/31/2004	5/31/2004	edit delete
Task 2.2 Design riser pressurization trials and conduct simulations	Complete	Pgm Mgr	5/1/2002	5/1/2002	edit delete
Task 2.3 Perform riser pressurization trials for simple shapes	Complete	Pgm Mgr	5/31/2003	5/31/2003	edit delete
Task 2.4 Perform riser pressurization trials for production part	Complete	Pgm Mgr	5/31/2003	5/31/2003	edit delete
Task 3.2 Review literature and develop model equations	Complete	Pgm Mgr	7/31/2002	7/31/2002	edit delete

Percent of milestones completed:
(15 total)

83%

Project Milestones in CPS



Linked with MYPP Milestones



Focus Area 2. Innovative Casting Process:

Barrier-Pathway Approach and Project Selection

Barriers



- Absence of accurate simulation tools
- Difficulty producing thin-wall, high performance castings
- Absence of real-time sensors and controls
- Difficulty in rapid prototyping

Pathways



- Develop simulation tools for lost foam casting.
- Develop process capability for Magnesium and Steel Lost foam Casting.
- Develop computer simulations to design tighter tolerances in die casting
- Develop the technology for low cost semisolid metals
- Improvements and diversification in permanent mold castings and design capabilities

Metrics

Metric	2020
Energy Savings	70.3 trillion Btu
Cost Savings	\$390.68 million
Carbon Reduction	0.43 MMTc

**Issued the *Melting and Innovative Casting* solicitation in FY03;
projects selected based on formal Merit Review**



Innovative Casting R&D Pathways : Assumptions & Targets

Energy

- A 10% reduction in scrap and a 10% improvement in yield, reducing the amount of metal which must be melted per ton of casting shipped, thereby reducing energy requirements.

Markets

- Average commercial introduction in 2008
- Adopted by 54% of the applicable U.S. metal casting market
- Market saturation in 15 years

Other

- DOE gets credit for all achieved energy savings

Note: This area consists of 28 projects. The average commercial introduction, years of saturation, and market penetration was taken from GPRA 2005

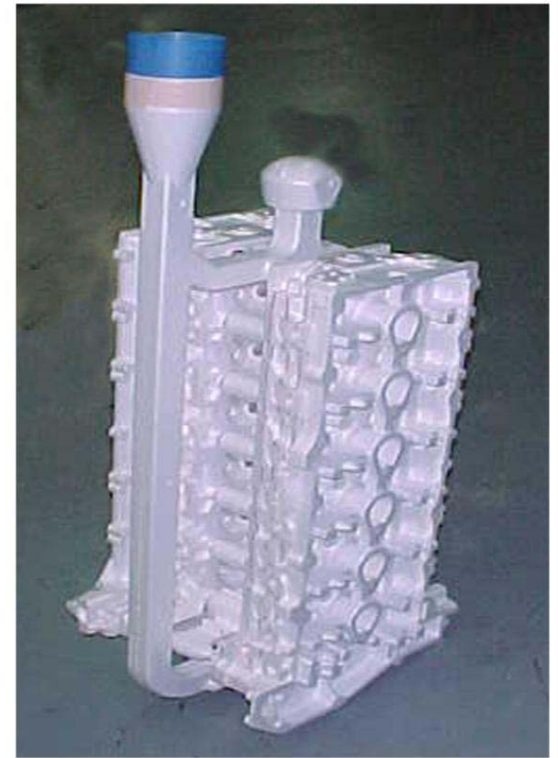


Examples of Innovative Casting Projects

Computer Models and Alloy Diversification for Lost Foam

Advanced Lost Foam Technology, Phase V

- Quantification and Standardization of Pattern Properties for Control of the Lost Foam Process
- Development of Computational Fluid Dynamics Tools for Modeling the Blowing and Steaming of Expandable Polystyrene (EPS) Patterns for Lost Foam Casting
- Real Time X-Ray for Monitoring Metal Filling
- Defect Prediction/Reduction

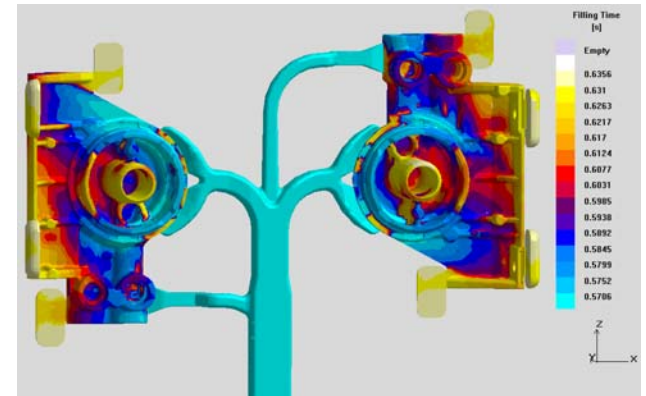




Examples of Innovative Casting Projects

Design Tools to Improve Die Casting Applications

- Understanding the Relationship between Die Filling and Part Quality in Die Casting
- Prediction of Part Distortion in Die Casting (Phase III)
- Computer Modeling of the Mechanical Performance of Die Casting Dies
- Effects of Die Design & Dimensional Features on Thermal Fatigue Cracking of Die Casting Dies
- Integration of RSP Tooling with Rapid Prototyping for Die Casting Applications
- Castability Assessment and Data Integration for Die Casting Design





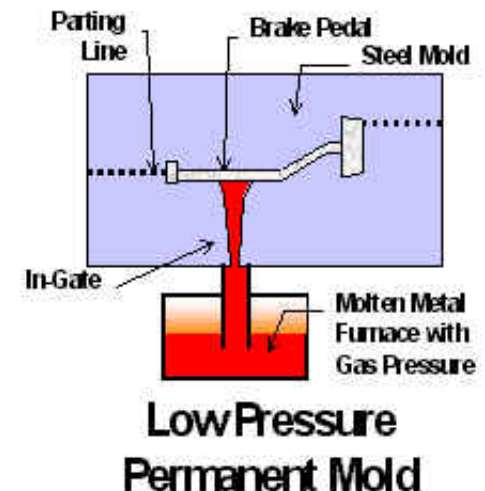
Examples of Innovative Casting Projects

Low Cost Semisolid Metal Feedstock

- Manufacture of Semisolid Metals (SSM) Feedstock

Improvements & Diversification in Permanent Mold Castings

- Investigation of Heat Transfer at the Mold/Metal Interface in Permanent Mold Casting of Light Alloys
- Gating of Permanent Mold Aluminum Casting
- Grain Refinement of Permanent Mold Cast Copper Base Alloys





Program Management Resources

- **Headquarters Project Management:**

- Ehr Ping HuangFu
- Assistance from expert consultants (e.g., M. Blair, R. Eppich, J. Santner, S. Udvardy)

- **Golden Field Office**

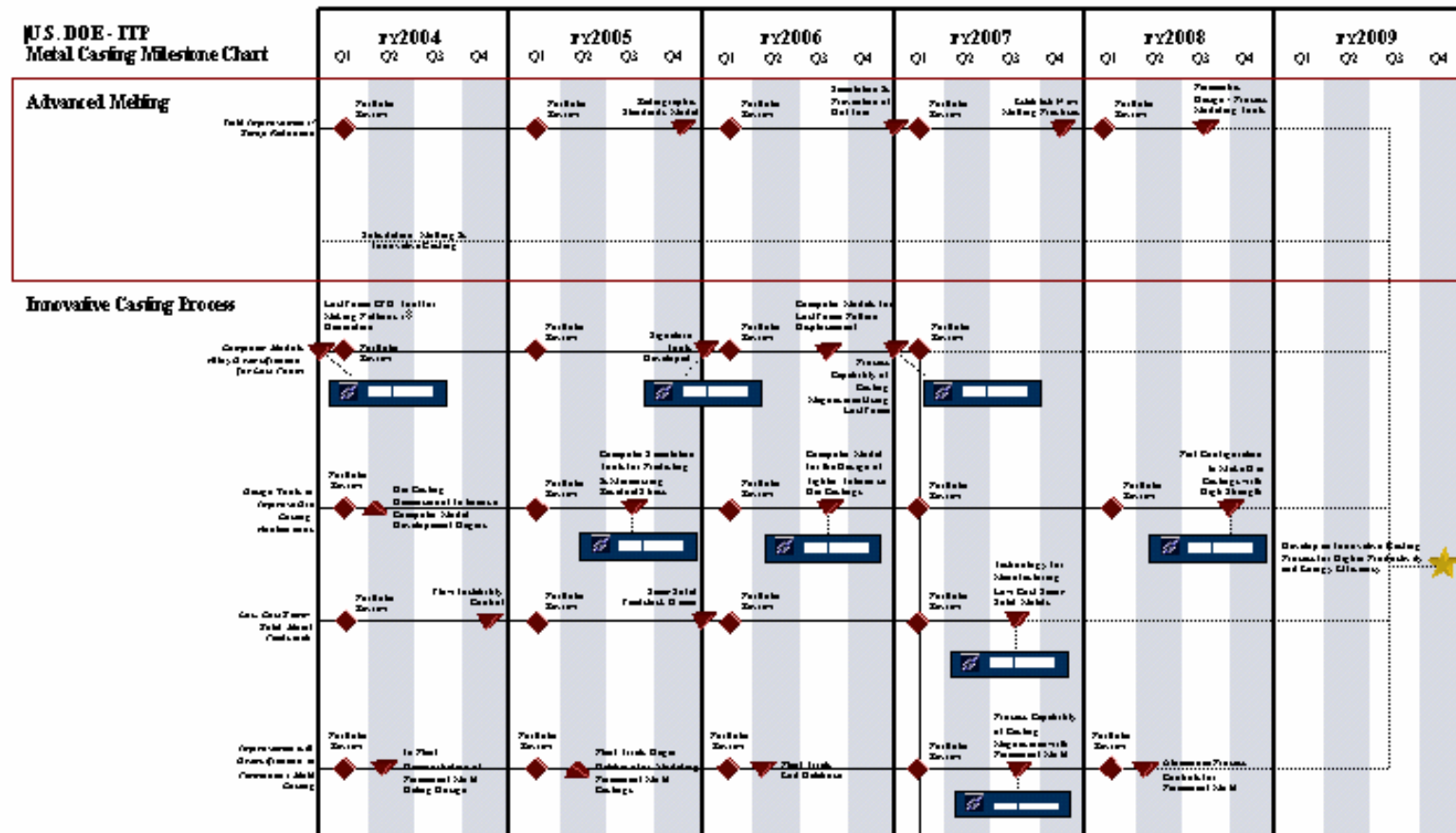
- Project Manager:
Aichbhaumik, Debo
Jha, Mahesh
- Contract Administrator
- Financial Accounting





Program Review and Assessment

- Rigorous evaluation process for program and projects:
 - Annual portfolio review (most recently October 03)
 - Quarterly milestone review (most recently December 03)
 - Ongoing project management by the field office
 - Commercialization planning
- Annual analysis of expected benefits (in accordance with Government Performance and Results Act) serves multiple purposes:
 - Up-front program planning and project selection
 - Benefits projection and project justification





Key Milestones

Milestone

Expected Completion

Advanced Melting

- | | |
|--|-------|
| • Radiographic Standards Model Developed | 08/05 |
| • Simulation & Prevention of Hot Tear | 09/06 |
| • Parametric Design/Process Modeling Tools | 06/08 |

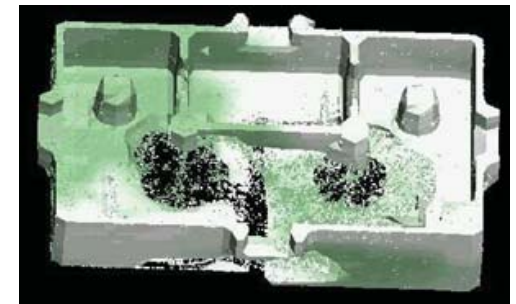
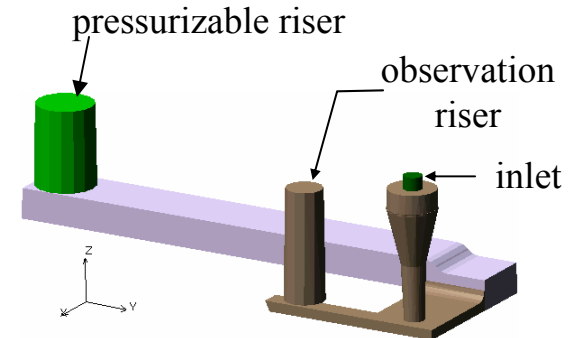
Innovative Casting Processes

- | | |
|---|-------|
| • Develop Signature Tools | 08/04 |
| • Computer Models for Lost Foam Pattern Displacement | 06/06 |
| • Process Capability of Casting Magnesium Using Lost Foam | 10/07 |
| • Computer Simulation Tools for predicting & Minimizing Residual Stress | 06/05 |
| • Computer Model for the Design of Tighter Tolerance Die Castings | 06/06 |
| • Part Configuration to Make Die Castings with High Strength | 08/08 |
| • Semisolid Feedstock Demo | 09/05 |
| • Technology for Manufacturing Low-Cost Semisolid Metals | 07/07 |
| • Plant Trials begin for Database Modeling Permanent Mold Castings | 03/05 |
| • Process Capability of Casting Magnesium with Permanent Mold | 05/07 |



FY03-04 Accomplishments

- **Yield Improvement and Defect Reduction in Steel Castings**
 - Developed new feeding distance rules for risering and pressurization of risers that will reduce shrinkage and increase yield
- **Development of a Computational Fluid Dynamics Tool for Modeling the Blowing of EPS Patterns for Lost Foam**
 - Developed a computational tool that allows, for the first time, an analytical approach to design EPS pattern molds, producing higher quality patterns with reduced lead times.



Box Pattern Filling



FY03-04 Accomplishments

- **Simple Visualization Techniques for Die Casting Part and Design “CastView”**
 - Commercially available
 - “CastView” is intended to help Minimize flow-related problems, thermal related problems, and solidification defects in die cast parts.
- **Low-Cost Manufacture of Semi-Solid (SSM) Feedstock**
 - Researchers developed a novel slurry-making process (termed Continuous Rheoconversion Process), which can generate near ideal semisolid structures within a large process window
 - Beta Site Trials are underway



CRP - Apparatus



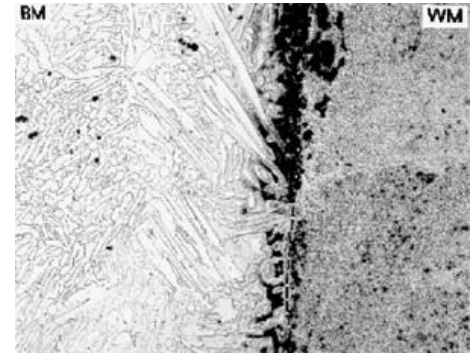
FY03-04 Accomplishments

- **Gating of Permanent Mold Aluminum Casting**
 - Determined the requirements to produce defect-free aluminum castings including optimized gating design, introduction of filters and the utilization of proper degassing methods in permanent mold casting
 - Excellent results were obtained during field test
- **Investigation of Heat Transfer at the Mold Metal Interface in Permanent Mold**
 - Developed and experimentally verified a new approach to estimating interfacial heat transfer in Indirect Squeeze Casting and Low Pressure Permanent Mold Casting



FY03-04 Accomplishments

- **Clean Cast Steel**
 - Developed a method to improve casting product quality by removing or minimizing oxides.
 - Reduces scrap and heat treatment requirements
- **Effects of Composition and Processing of High Performance Die Steels**
 - Determined which selected compositions for die steels are superior to other steels used in the past.
 - Extends die life by 20 to 30 percent



**Weld fusion boundary pitting
corrosion-sensitive material
ASTM A890-4A (2205 type).**



Attracting a New Workforce for the Metal Casting Industry

- Increasingly difficult for foundries to attract quality degreed technical staff
- Necessary for a healthy, vibrant U.S. metal casting industry
- Benefits of Metal Casting IOF Research
 - Emphasis on university-based R&D involves large number of students
 - Students trained in latest techniques, help transfer knowledge to industry as they enter workforce
 - New workforce educated in importance of energy efficiency in all process phases
- As of FY 2003 there have been 326 students that have participated in Metal Casting IOF Research.
 - Of these **326 students**, it is estimated that **152 now work in the metal casting industry**
 - 52 are still in school finishing their degrees or pursuing advanced degrees.



CastView Helps Save Time and Money for a Die Caster

- Metal Casting research conducted by Ohio State University has developed a software package named CastView that provides computer simulations of die filling conditions
- Excel Dryer utilized this software to improve the design of a Xlerator hand dryer, a seven pound zinc die casting product.
 - CastView saved time and money by quickly running through several runner/gating simulations to determine the optimal configuration





Metalcasting Project Leveraged for DOD's Silent Propeller Casting

- The ITP project of “Yield Improvement in Steel Casting” at the University of Iowa is also making significant impact on the development of Navy’s secret silent ship propellers
- From the Navy's standpoint, the benefits of this leveraged ITP technology is increased solidification integrity of the propellers, resulting improved alloy mechanical properties, and lower propeller cost

